DYWIDAG-SYSTEMS INTERNATIONAL

DYWIDAG Multistrand Stay Cable Systems

Alamillo Bridge, Sevilla, Spain
28 DYNA Bond® Stay Cables
Maximum cable length: 292 m
Cable size: DB-E61

Pitt River Bridge, Vancouver, Canada
96 DYNA Grip® Stay Cables
Maximum cable length: 99 m
Cable sizes: DG-P31, DG-P61

Gajo Arch Bridge, Geoje City, South Korea
80 DYNA Grip® Stay Cables
Maximum cable length: 31 m
Cable size: DG-P12

La Plata Bridge, Puerto Rico
96 DYNA Bond® Stay Cables
Maximum cable length: 90.1 m
Cable sizes: DB-P27, DB-P37

Ziegelgraben Bridge, Germany
32 DYNA Grip® Stay Cables
Maximum cable length: 176 m
Cable size: DG-P37

North Avenue Bridge, USA
24 DYNA Grip® Stay Cables
Maximum cable length: 26 m
Cable sizes: DG-P19, DG-P31

Content

General

Cable stayed bridges are very efficient structural systems with light weight superstructures and large lever arms. The most important elements of these aesthetically pleasing and often dramatic structures are the closely spaced stay cables which transfer the loads to the foundation via the pylon. It is essential that these tensile elements are durable and easy to maintain. They are generally designed to be restressable and replaceable.

DYWIDAG has been involved in the development, construction and execution of stay cables and cable supported structures since 1970.

Based on internationally recognized guidelines for stay cables combined with our own design criteria of the world wide renowned DYWIDAG Multistrand tendons, we first developed stay cables with bars and applied them for large bridges (for example the Dame Point Bridge, Florida USA; main span 396 m).

Afterwards, we were able to take advantage of our many years of experience and expertise in post-tensioning and prestressed concrete construction, particularly in the field of long span bridges.

DYWIDAG Multistrand Stay Cables were developed in the eighties to accommodate ever increasing spans and the resulting need for economical high capacity cables. Today, strand cables are widely used for many types of structures. This brochure provides an overview of DYWIDAG Multistrand Stay Cable Systems.The special use of stay cables for extradosed tendons is also included. More detailed information is available on request.

Quality Assurance

To ensure high quality and consequently, the performance and durability of DYWIDAG Stay Cables, all components are subjected to quality tests according to our quality assurance system. DSI is ISO 9001 certified.

DSI maintains an internal quality control test lab in Germany for in-house testing of geometry, material and performance.


IQNet
THE INTERNATIONAL CERTIFICATION NETWORK
CERTIFICATE
DSI Holding GmbH
ISO 9001 : 2008

DYWIDAG Stay Cables

DYWIDAG Stay Cables are normally available in standard sizes up to 109 strands per anchorage. This maximum size was extended for the Maumee River Crossing project/USA, where DSI developed a cable with up to 156 strands. This cable is the largest in the world and has been proven successfully in static, dynamic and leak tightness tests.

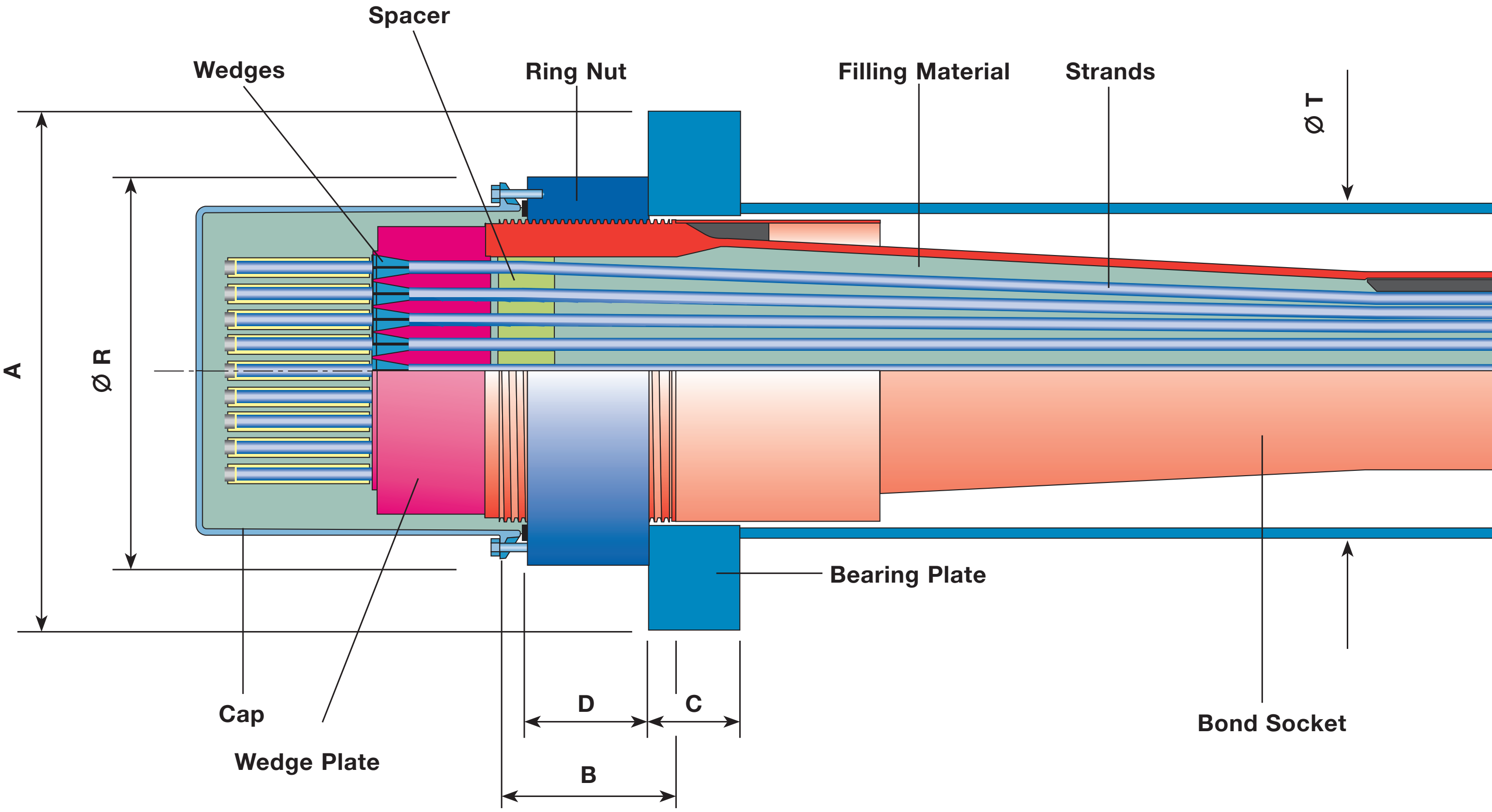
To meet market demands and requirements of international standards, DSI provides stay cables with two basic types of anchorages:

– DYNA Bond® Anchorage
– DYNA Grip® Anchorage

The DYNA Bond® Anchorage is an anchorage with additional internal bond. It is normally grouted after application of the permanent loads of the superstructure.

The DYNA Grip® Anchorage is an anchorage without bond that permits monitoring and replacement of individual strands of a stay during its entire service life.

DYWIDAG Stay Cables are designed according to acknowledged international requirements e.g. PTI, fib or CIP/Setra.



DYNA Bond® Anchorage

The DYNA Bond® Anchorage consists of a conical steel pipe (bond socket) supporting a wedge plate where the strands are anchored with 3-part-wedges. A ring nut is fitted on the threaded end of the bond socket and distributes the cable force through a bearing plate into the structure. During the construction phase prior to grouting the bond socket, all the applied loads are supported directly by the wedges.

After filling the bond socket with cement or epoxy grout, all additional loads (including dynamic loads from traffic, vibrations and earthquakes) are then partly resisted by the wedges. They are then partly transmitted by bond between the strands and the grout via the bond socket directly to the bearing plate and the supporting structure (only the bond socket needs to be grouted to achieve the behaviour described above).

DYNA Bond® Anchorages have an excellent fatigue resistance because the bond action in the bond socket substantially reduces the magnitude of the dynamic loads reaching the wedge anchorage. Fatigue tests have proven that a stress range of up to 240 N/mm^2 (upper stress 0,45 GUTS) may be safely resisted for over 2 million cycles.

Additional advantages of DYNA Bond® Anchorages:

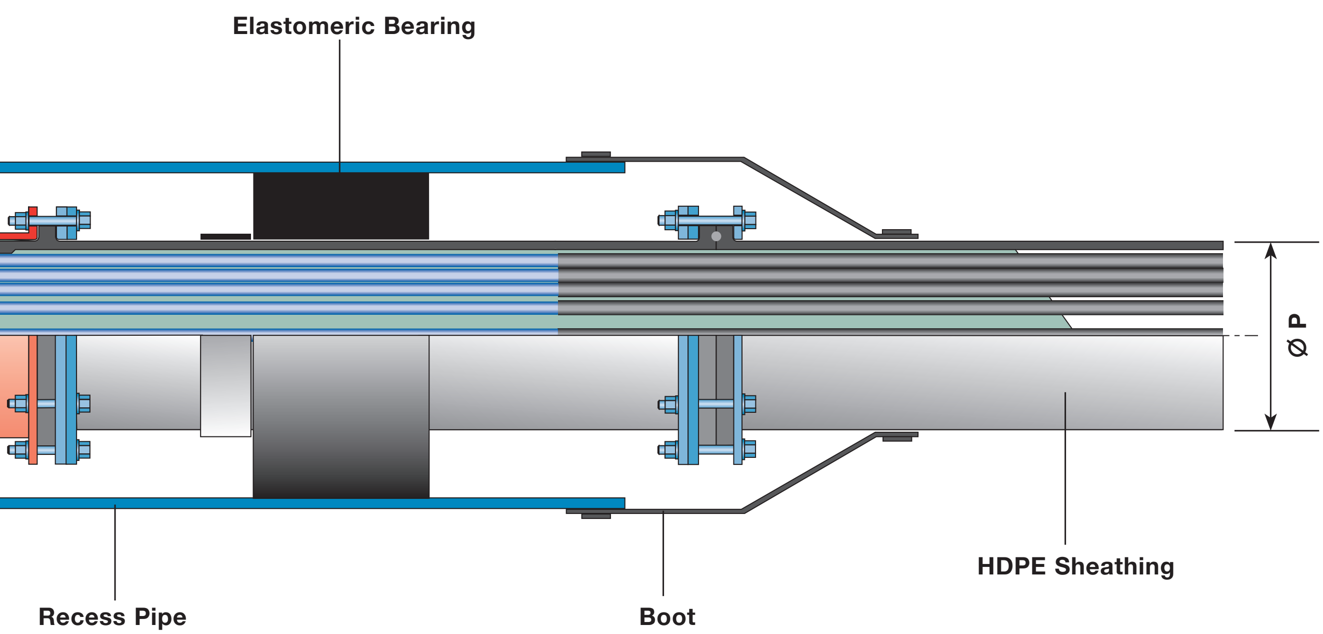
- redundant load carrying system
- reliable corrosion protection for the sensitive anchorage area because all voids in the anchorage zone are filled with a stable and robust filler
- enhanced fire resistance and protection against vandalism, impact loads and blast effects
- easy fixation of half shells directly on the grouted PE sheathing for the connection of external dampers

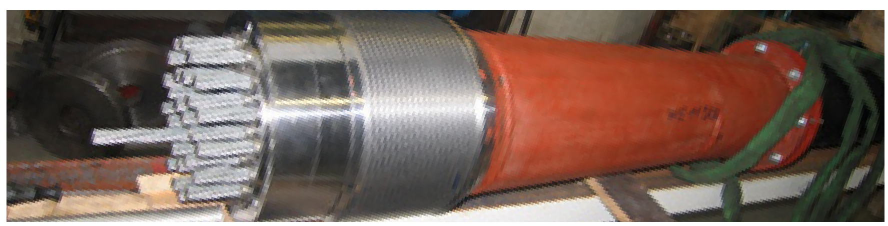
Another important construction detail is the use of an elastomeric bearing at a certain distance away from the anchor block. The most important requirement for the design of the bearing is to prevent the introduction of harmful bending in the anchorage area.

Since the injection of the grout extends beyond the bearing, the DYNA Bond® Anchorage provides a clear statical system for the absorption of bending loads due to lateral cable movements (cable rotation).

Kap Shui Mun Bridge, Hong Kong

DYNA Bond® Anchorage



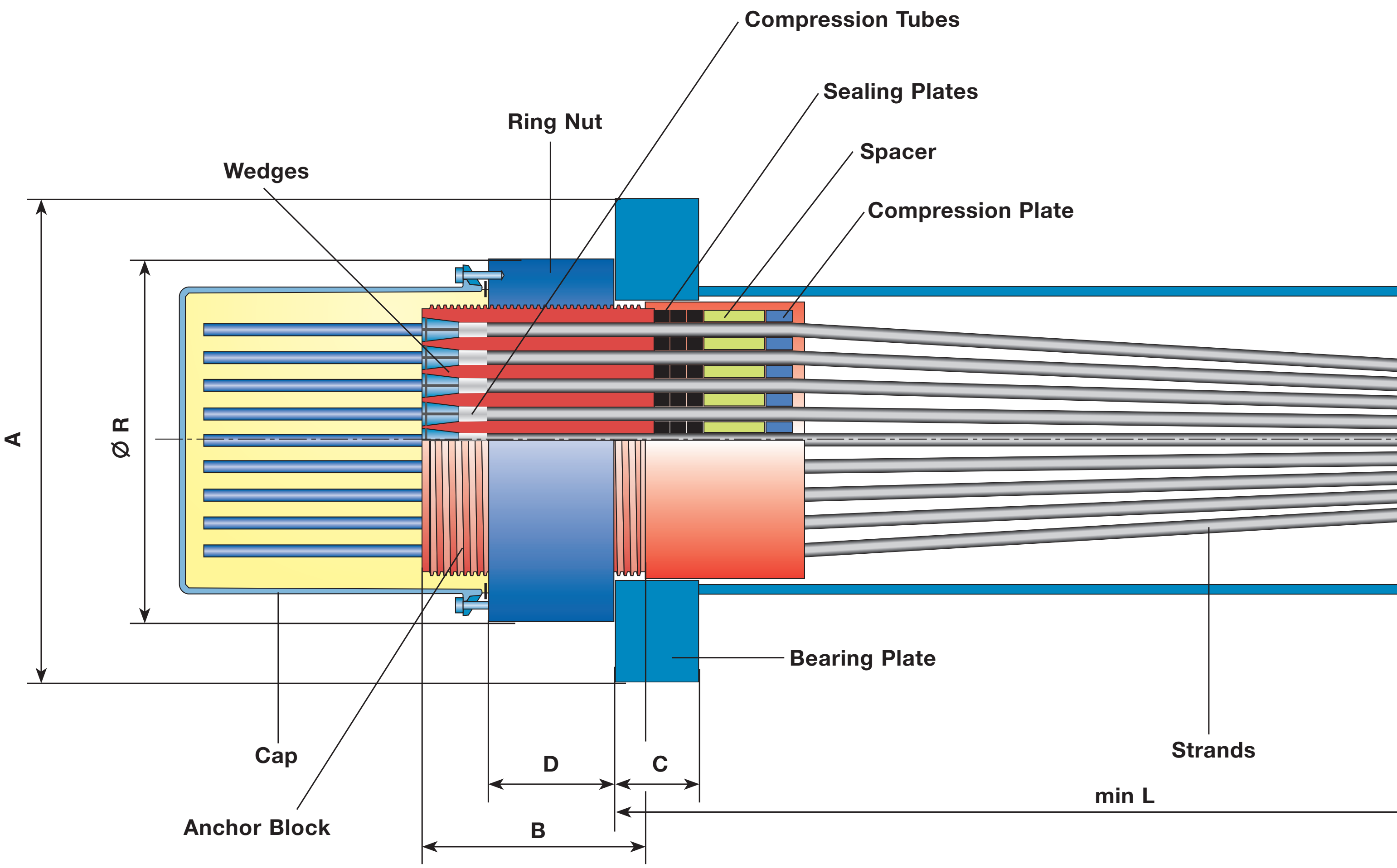


DYNA Bond® Anchorage
(forces calculated with strands 0,62" St 1620/1860)

Cable type		DB-P12	DB-P19	DB-P27	DB-P37	DB-P48	DB-P61	DB-P75	DB-P91	DB-P108
No. of strands		12	19	27	37	48	61	75	91	108
Forces [kN]										
ultimate load (GUTS)		3.348	5.301	7.533	10.323	13.392	17.019	20.925	25.389	30.132
working load (0,45 x GUTS)		1.507	2.385	3.390	4.645	6.026	7.659	9.416	11.425	13.559
Dimensions [mm]										
bearing plate	A	300	370	430	500	580	640	715	780	855
bearing plate	C	50	60	70	80	90	100	110	120	130
thread*	B	160	170	180	190	205	220	240	260	280
ring nut	D	90	100	110	120	135	150	170	190	210
ring nut	Ø R	244	287	326	378	434	480	536	584	636
recess pipe	Ø T	219	245	299	324	394	419	470	508	559
HDPE sheathing	Ø P	110	125	160	180	200	225	250	280	315

* standard length, larger lengths can be provided upon special request

Subject to modification



DYNA Grip® Anchorage

Project specifications often require individual strands of stay cables to be inspectable and, if necessary, replaceable. For these requirements, DSI developed the DYNA Grip® Anchorage, providing the opportunity to inspect individual strands without damaging the stay cable and to replace strands, if necessary.

The DYNA Grip® Anchorage consists of an anchor block in which the strands are anchored by 3 part-wedges with high dynamic performance. A ring nut is threaded on the anchor block to transmit the cable force via the bearing plate into the structure. A steel pipe which incorporates centering and sealing provisions for the strands is welded to the anchor block.

Fatigue tests have proven a dynamic stress range of up to 200 N/mm² (upper stress 0,45 GUTS at 2 million load cycles with 0,6° inclined anchorages). Fatigue tests on single strands with DYNA Grip® wedges with a dynamic stress range of 250 N/mm² and 10 million load cycles were also successfully performed.

Special features of DYNA Grip® Anchorages:

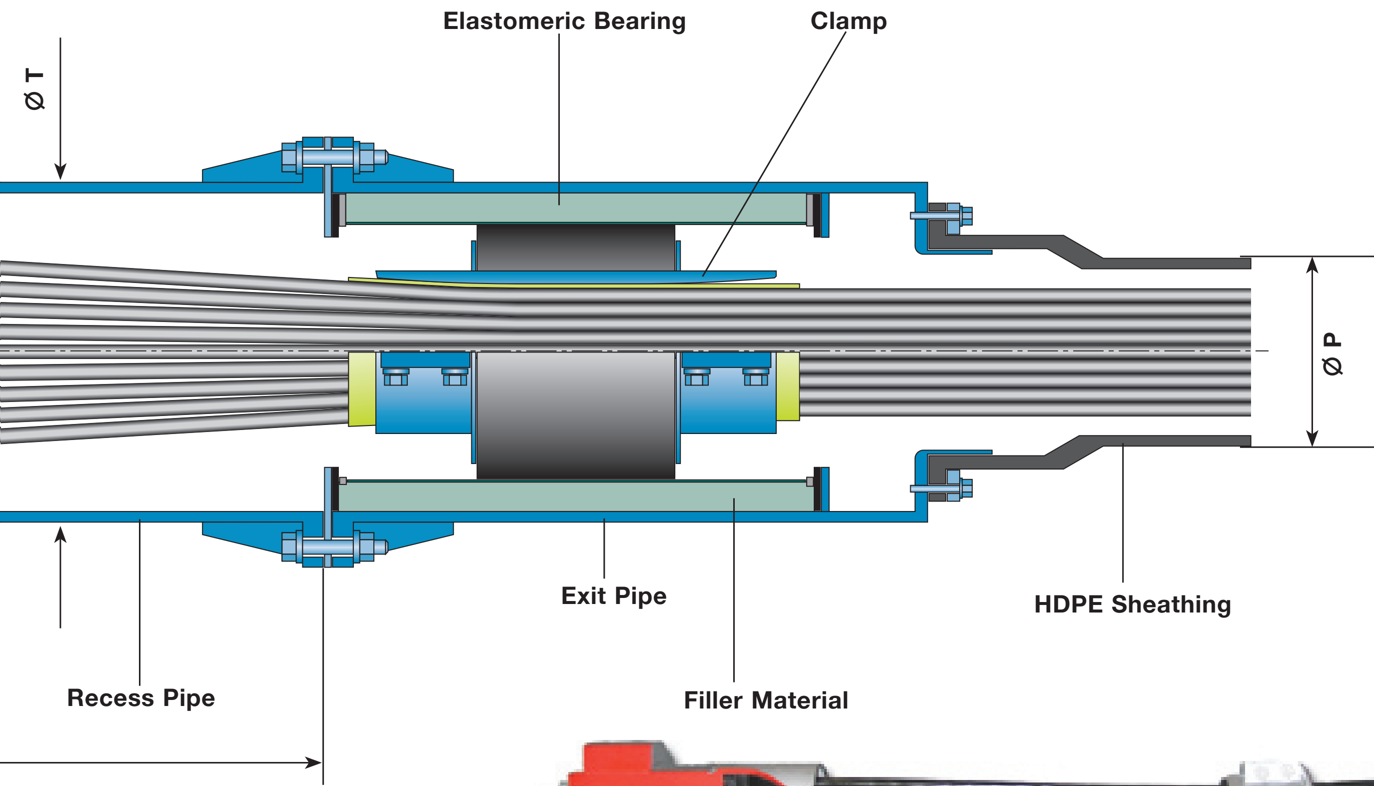
- the factory applied corrosion protection of the PE-coated strands continues directly up to the wedges. This significantly reduces the space in the anchorage which is to be filled with corrosion protection compound and therefore improves durability.
- an exact cutting to length of the strands and removal of the PE coating is not necessary. Using special equipment, the PE-coating is removed by using a DSI developed and patented procedure during the first stressing. In cases where subsequent stressing actions are necessary, the remaining PE-coating is compressed by the compression tubes, held by the wedges, while the strand is pulled through and elongated by the jack.
- restressing and replacement of individual strands, as well as of the complete cable, is possible.
- strands and PE-coating can be pulled through the anchorage.

An exchange of single strands can thus be performed directly at the anchorages without traffic limitations.

Similar to the DYNA Bond® Anchorage, an elastomeric bearing is installed at a certain distance from the anchor block to reduce the bending stresses in the strands caused by cable rotation.

A clamp, installed after stressing on the strand bundle, keeps the strand in a compact hexagonal pattern and acts as support for the elastomeric bearing. The drawing above shows a version that is able to accommodate construction tolerances between the cable axis and the axis of the recess pipe. Other details are also used.

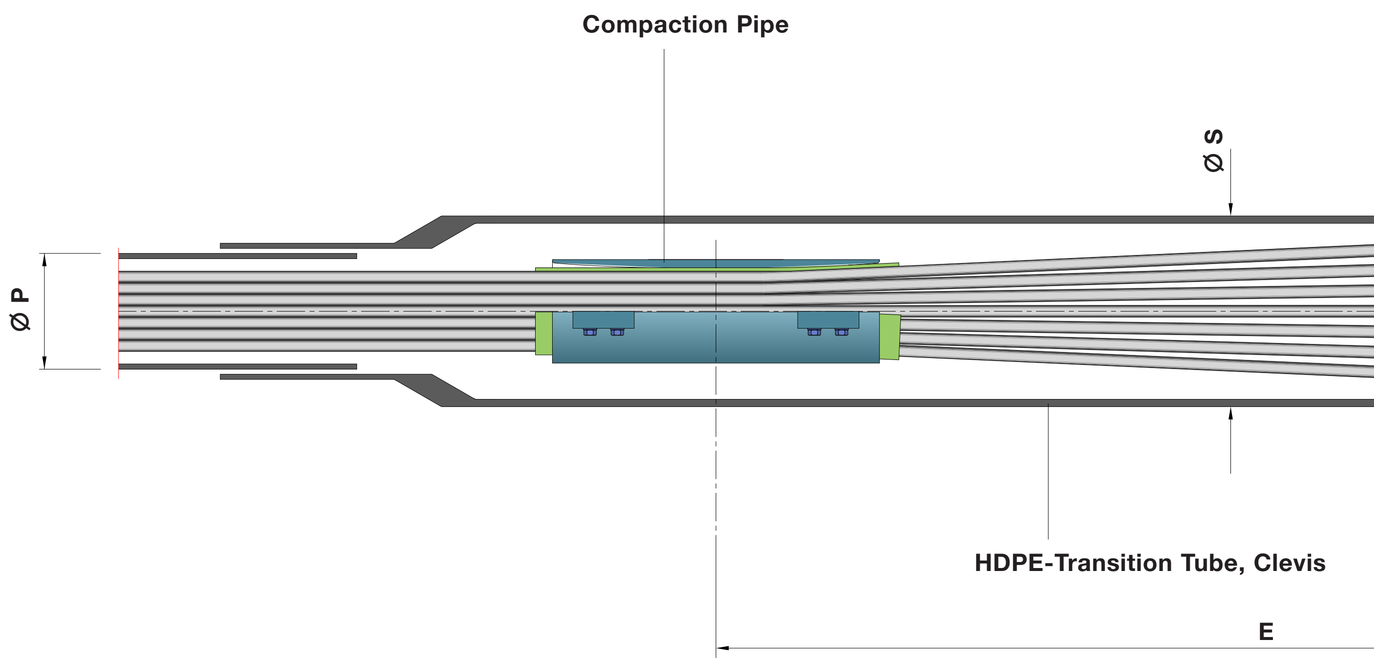
DYNA Grip® Anchorage



DYNA Grip® Anchorage
(forces calculated with strands 0,62" St 1620/1860)

Cable type		DG-P12	DG-P19	DG-P31	DG-P37	DG-P55	DG-P61	DG-P73	DG-P91	DG-P109*
No. of strands		12	19	31	37	55	61	73	91	109
Forces [kN]										
ultimate load (GUTS)		3.348	5.301	8.649	10.323	15.345	17.019	20.367	25.389	30.411
working load (0,45 x GUTS)		1.507	2.385	3.892	4.645	6.905	7.659	9.165	11.425	13.685
Dimensions [mm]										
bearing plate	☐A	300	370	460	500	600	640	715	780	855
bearing plate	C	50	60	75	80	95	100	110	120	130
thread**	B	200	220	230	240	270	275	290	310	340
ring nut	D	90	110	120	130	160	165	180	200	230
ring nut	Ø R	244	287	350	378	440	480	536	600	636
recess pipe	Ø T	219	245	299	324	368	406	457	495	521
recess pipe	min L	810	970	1.240	1.390	1.620	1.780	1.930	2.210	2.890
HDPE sheathing	Ø P	110	125	160	180	200	225	250	280	315

* up to 156 on special request
** standard length, changeable on special request
Subject to modification



Clevis Anchorage for DSI Stay Cables

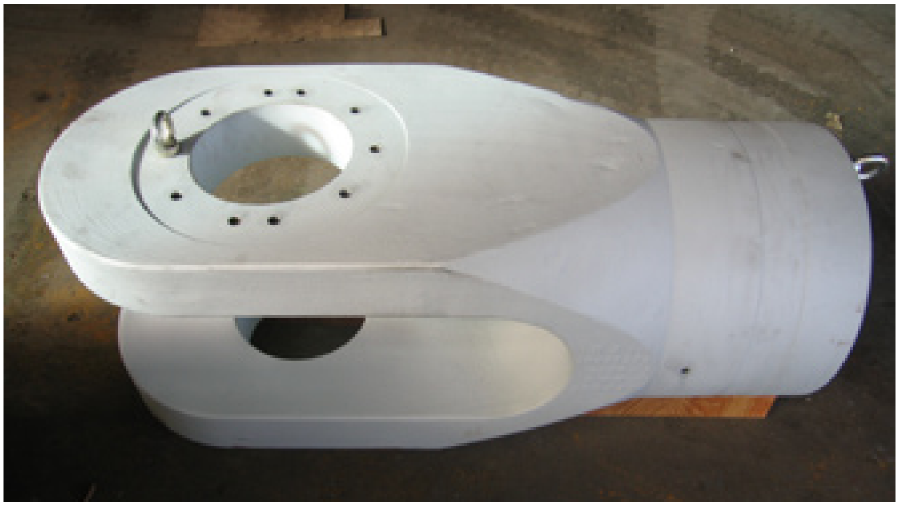
Architectural requirements for the design of stay cable bridges are steadily increasing. This is especially true for the pylon, which needs to be as slim and elegant as possible. As a consequence, the space inside the pylon is often insufficient for common stay cable anchorages that are supported by bearing plates. Frequently, solutions are needed in which the stay cables are connected to the structure outside of the pylon.

For this purpose, DSI newly developed the DYNA Grip® Clevis Anchorage for strand cable types DG-P12, 37 and 61, offering an economic alternative to conventional systems used so far.

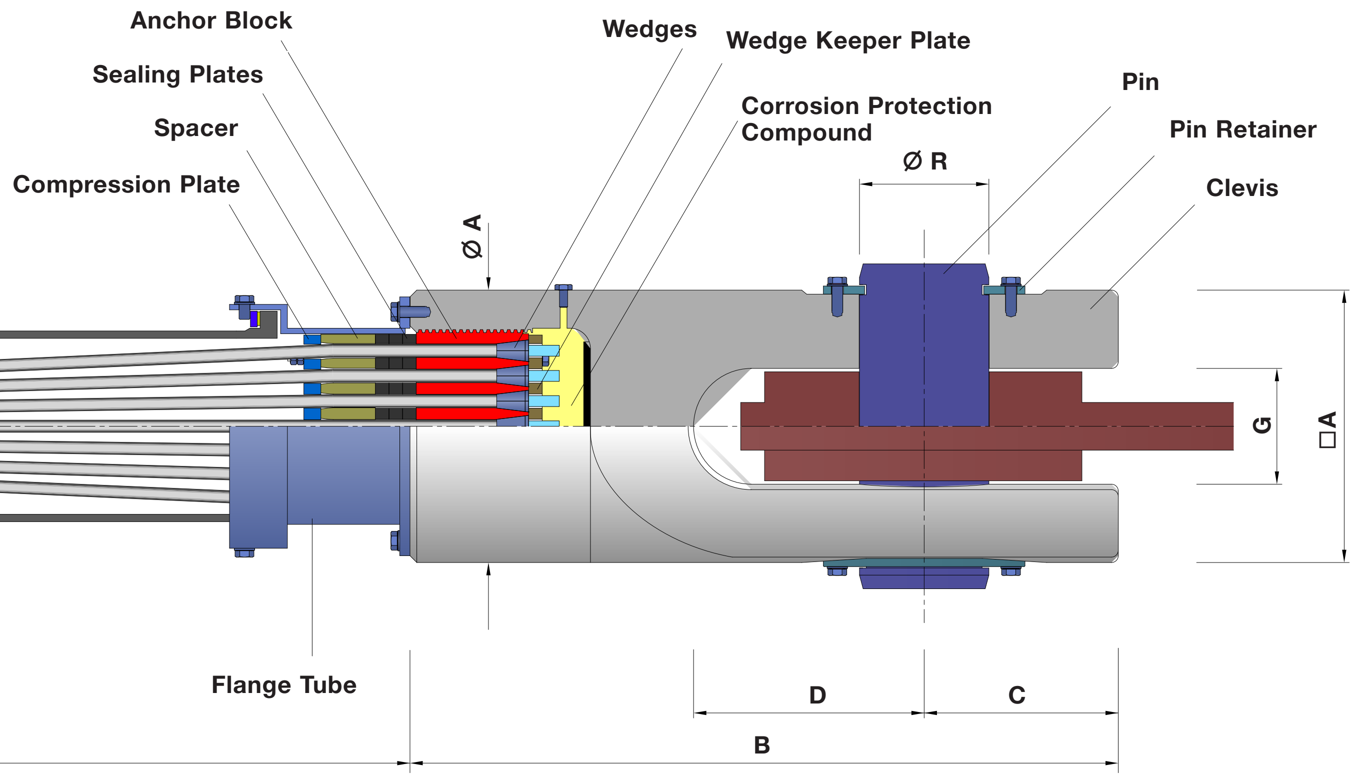
The drawing above shows the clevis fastened to the structure via a gusset plate and a pin. At the opposite side, a DYNA Grip® anchor block is screwed into an inside thread. The anchorage is connected to the stay cable sheathing by a flange tube that also contains the sealing unit of the anchorage. Similar to the common DYNA Grip® Anchorage, a compaction pipe keeps the strand bundle in a hexagonal pattern.

Special features of the DYNA Grip® Clevis Anchorage:

- The complete strand cable can be easily pre-assembled on the superstructure and lifted into its final position afterwards.
- DSI offers special tools for the preassembly of the clevis as well as the mounting of the pin into the clevis hole.
- Restressing of individual strands as well as the replacement of the complete strand bundle is possible.
- This system also offers other advantages known from the DYNA Grip® system.



DYNA Grip® Anchorage Type Clevis



Fatigue tests were carried out at the Technical University of Munich, respecting an inclination of 0,6° - even towards the inflexible centerline - and an upper load of 0,45 GUTS (with a stress range of 200 N/mm² at 2 million load cycles) as required by the fib Bulletin 30. These dynamic tests, as well as the subsequent static tensile tests, were performed with outstanding success.

The clevis anchorage is not only suitable for stay cable bridges, but can also be used for arch bridge hangers, where available space in the arch is too small for aligning ordinary fixed anchors.

DYNA Grip® Anchorage Type Clevis
(forces calculated with strands 0,62" St 1620/1860)

Cable type		**DG-P12**	**DG-P37**	**DG-P61**
No. of strands		12	37	61
Dimensions [mm]				
clevis	Ø A □A	270	400	480
clevis length	B	900	1.040	1.230
clevis	C	185	285	340
clevis	D	385	340	440
transition length	E	1.000	1.700	2.100
gusset plate	G	130	160	230
gusset plate hole	Ø R	122	192	242
HDPE transition tube, clevis	Ø S	200	280	355
HDPE sheathing	Ø P	110	180	225

Subject to modification

Strands, Wedges and Corrosion Protection

DYWIDAG Stay Cables use strands that meet the requirements of **fib and PTI-Recommendations** for stay cables, **ASTM**, **BS** as well as other national or international standards.

Generally the following types of strands are used for both anchor types:

- consisting of 7 cold-drawn galvanized wires
- diameters up to 0.62" and steel grades up to 1860 mm²
- low relaxation strand
- PE-coated and waxed.

If required, epoxy-coated strands may also be used with either cable system.

Strands are anchored with specially treated 3-part wedges which are characterised by high fatigue resistance.

Wedges for Galvanized Strands

Slim Duct

For long span bridges, lateral wind loading on the cables is an issue that needs to be taken into account for the design of the pylon. To reduce the wind load, DSI offers slim sheathing in the form of reduced pipe diameters.

Threading of the strands is made more difficult because pipes are fuller than they would usually be.

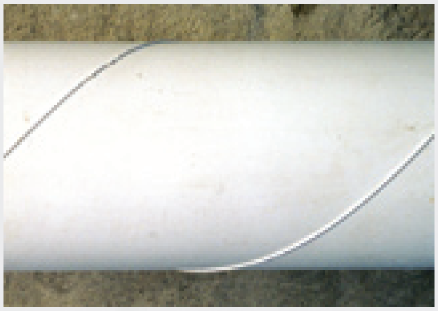
DSI developed new equipment for these special requirements and tested the modified installation procedure.

Slim Duct

Outer Sheathing

Standard HDPE-pipes are typically used for the outer casing of the DYWIDAG Stay Cables. They serve as protection against environmental influences and reduce the wind loads on the cable. Pipes may be supplied in a wide variety of UV-resistant colours. They can also be provided with an outer helix to suppress rain-wind induced cable vibrations.

Steel or stainless steel pipes are available on special request.



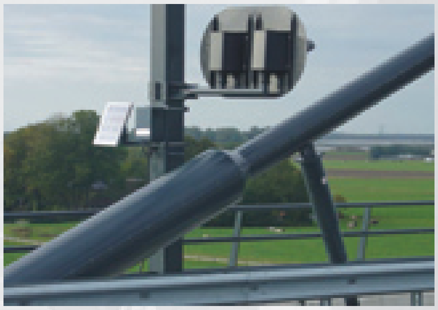
PE-Sheathing with Helix

Bearings and Dampers

Elastomeric bearings near the anchorages reduce the bending stresses in the anchorage zone and act as dampers against cable vibrations.

DYWIDAG stay cables can be equipped with devices facilitating the immediate or ex-post assembly of external dampers.

DSI provides additional damping devices to reduce cable vibrations on request.



Installed External Damper

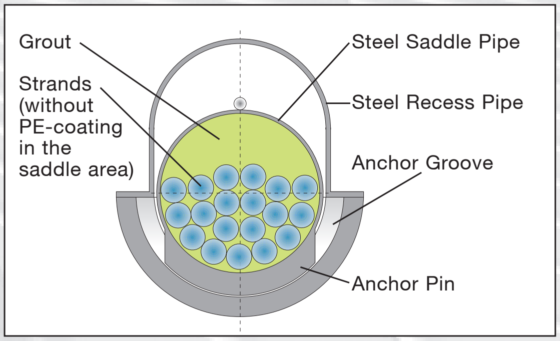
Test Installation of a Hydraulic Damper

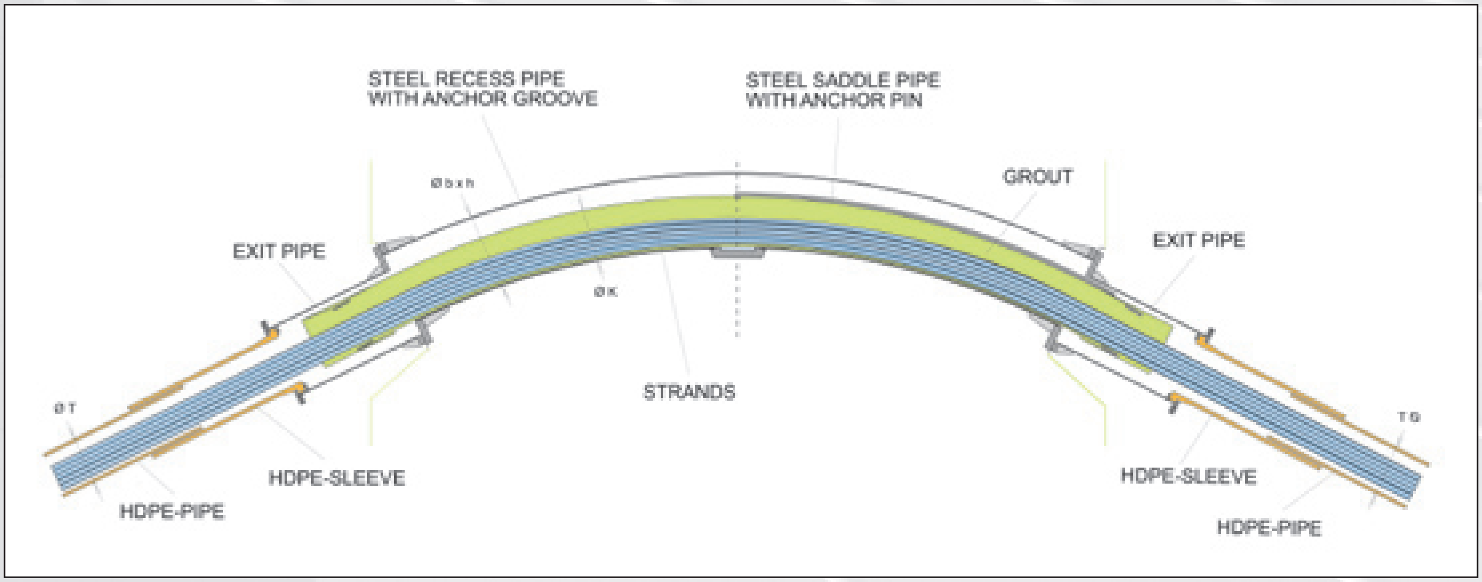
Saddle

DYWIDAG-Systems International developed a saddle capable of transfering differential forces. It is replaceable due to an anchor groove - pin construction

Saddle Pipe Installation

Installed Saddle Construction





Saddle with Anchor Groove and Anchor Pin

Tests

DYWIDAG Stay Cables have been successfully tested in static and fatigue tests in compliance with **PTI** and/or **fib recommendations**. Tests with 0.6° inclined anchorages and the leak tightness test – required by fib bulletin 30 – were also successfully conducted.

Fatigue Test at the Technical University Munich

Anchorage of a Fatigue Test

Leak Tightness Test at DSI Laboratory

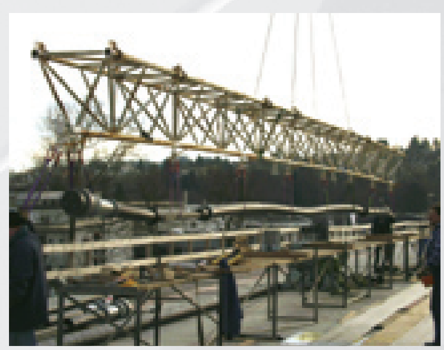
Installation

DSI has developed various methods to optimize and simplify the cable installation procedures depending on site specific space and time constraints.

- Prefabrication of cables on site:
  This method is preferably used for short cables. They are lifted into position with cranes.
  Due to favourable site conditions at the Alamillo cable stayed bridge in Spain, 300 m long locally prefabricated cables could be installed using a winch.

- Pushing strands into prefabricated sheathing:
  The sheathing is prefabricated on site and brought to the inclined position in the bridge. The strands are then pushed in one by one using a light pusher.

- Pulling strands into prefabricated sheathing:
  As above, the prefabricated sheathing is brought to the inclined position and strands are pulled in one by one, using small winches.



Stressing

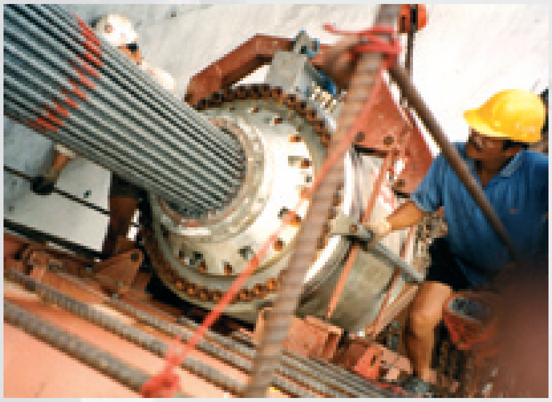
Depending on project requirements, DSI employs two different stressing methods.

1. Stressing with multistrand jacks
This procedure can be used for cables with DYNA Bond® Anchorages.

All strands in a cable are stressed simultaneously with one hydraulic jack attached to the anchorage.

Jacks up to a capacity of 15,000 kN are available.

The advantage of this method is the fast and accurate stressing operation of the cable in one step. However, it is important to provide sufficient working space at the anchorage and to be aware of the fact that special lifting devices may be needed to handle the jacks efficiently.



Multistrand Jack 15,000 kN

ConTen Jacks

ConTen Valve

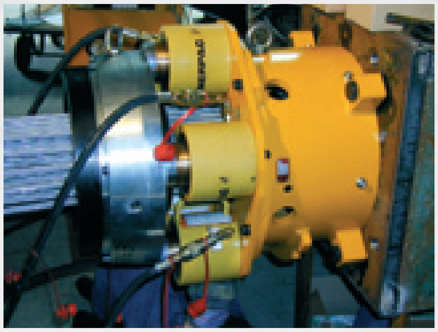
2. Stressing with monojacks using the ConTen-System
This patented procedure is applicable for both DSI DYNA Bond® and DYNA Grip® Stay Cable Systems.

All single strands are stressed immediately after being installed in the cable anchorages, thus optimising the entire installation process. A special calculation method has been developed by DSI to determine the force for the first strand and the corresponding forces for the subsequent strands in order to monitor the stressing operation up to the required final cable force.

A light weight monojack is placed on an already stressed strand, and an identical jack is placed on the strand to be stressed next. The jacks are hydraulically linked to compare the actual pressure in both jacks during stressing. This ConTen System permits an equalization of the force in all strands at the end of the stressing operation. In addition, the influence of temperature and load changes in the cables and in the structure during stressing are auto-matically eliminated. A new ConTen Valve has been developed and patented as an enhancement of the existing equipment. The working jack is connected to the Valve which is attached to a stressed strand. A regular hydraulic pump can be used with this new system.

Once structures are finished, cable forces can be adjusted by restressing or destressing of the complete cable via the ring nut (shims are used in the case of longer elongations). Special compact and light weight gradient jacks are available for adjusting the cable force and the bridge profile,if necessary.

→ see table on page 18



Gradient Jack

DSI Services

- Comprehensive consulting services
- Special design and installation planning
- Component manufacturing and delivery
- Installation: either turn-key using DSI staff or project supervision and staff training
- Inspection and maintenance services

DYNA Force Elasto-Magnetic Sensor

On many occasions during the construction and service life of the structure, it is crucial to know the force in the stay cable. Although there are many methods to measure the cable force, most of them are cumbersome, expensive and inaccurate. DYWIDAG has been involved in the development, testing and execution of DYNA Force™ to measure the force in the cable. DYNA Force™ is being used in cable stay bridges, cable system testing, building structures and geotechnical applications to monitor the force during stressing construction and the service life of the structure. DYNA Force™ can be used for bare, galvanised, epoxy-coated and greased-sheathed steel.

DYNA Force™ is manufactured based on the theory that the permeability of steel to a magnetic field changes with the stress level in the steel. By measuring the change in a magnetic field, the magnitude of the stress in the steel element can be obtained. The DYNA Force™ does not alter the characteristics of the tendon other than its magnetization. The permeability is a function of temperature and magnetization, and a calibration process eliminates the impact of these variables. The program takes into consideration the temperature change effect automatically. A portable Power Stress unit is attached to wire leads from the DYNA Force™. This unit will create the magnetic field, measure the residual value and then convert it to a direct force reading. The accuracy of the force measurement is within 1%. The DYNA Force™ system is robust, requires no maintenance and has no moving parts. It is composed of sensors and a Power Stress unit (read-out box).

Power Stress Unit

DYNA Force™ is installed over the strand during construction and a zero reading is taken before applying any stressing force. It is expected to have a similar service life as the bridge structure. This will allow the owner to regularly monitor the forces in the cables within minutes as a part of their inspection procedures without the need for lift-off equipment or other special expensive techniques. This will also avoid the inaccuracies and risks often associated with lift-off readings. A single person can do this job.

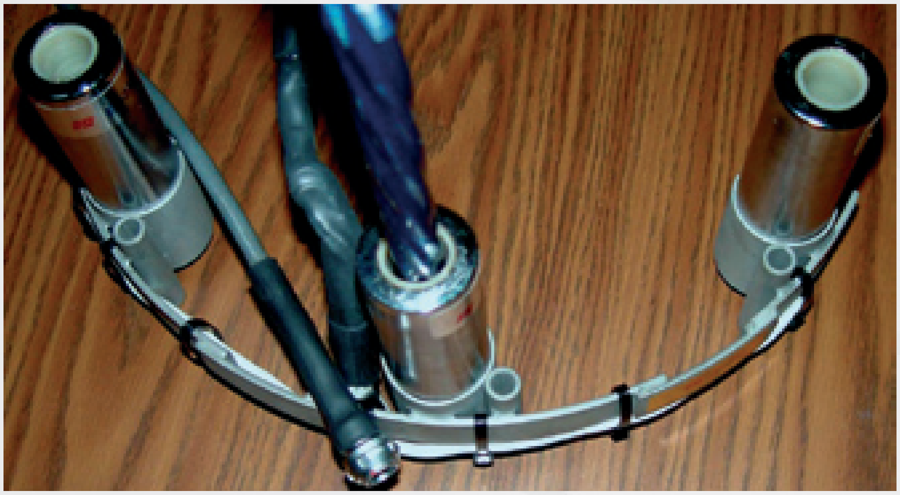
Quality Assurance

All DYNA Force™ sensors are professionally made in a quality controlled facility. Furthermore, each DYNA Force™ is tested and individually packed and numbered at the DSI facility before it is sent to the job site. Although many tests have been conducted in the development of the DYNA Force™, DSI carried out additional tests to simulate the performance of the system when placed within the anchorage zone of stay cables. In these tests DYNA Force™ sensors were placed near the center and on the outside of the strand bundle. The loads were applied using a stressing jack and the force was monitored using a very accurate load cell. The load cell readings were compared to the results from the Power Stress unit and very good correlation was obtained.

Practical Applications

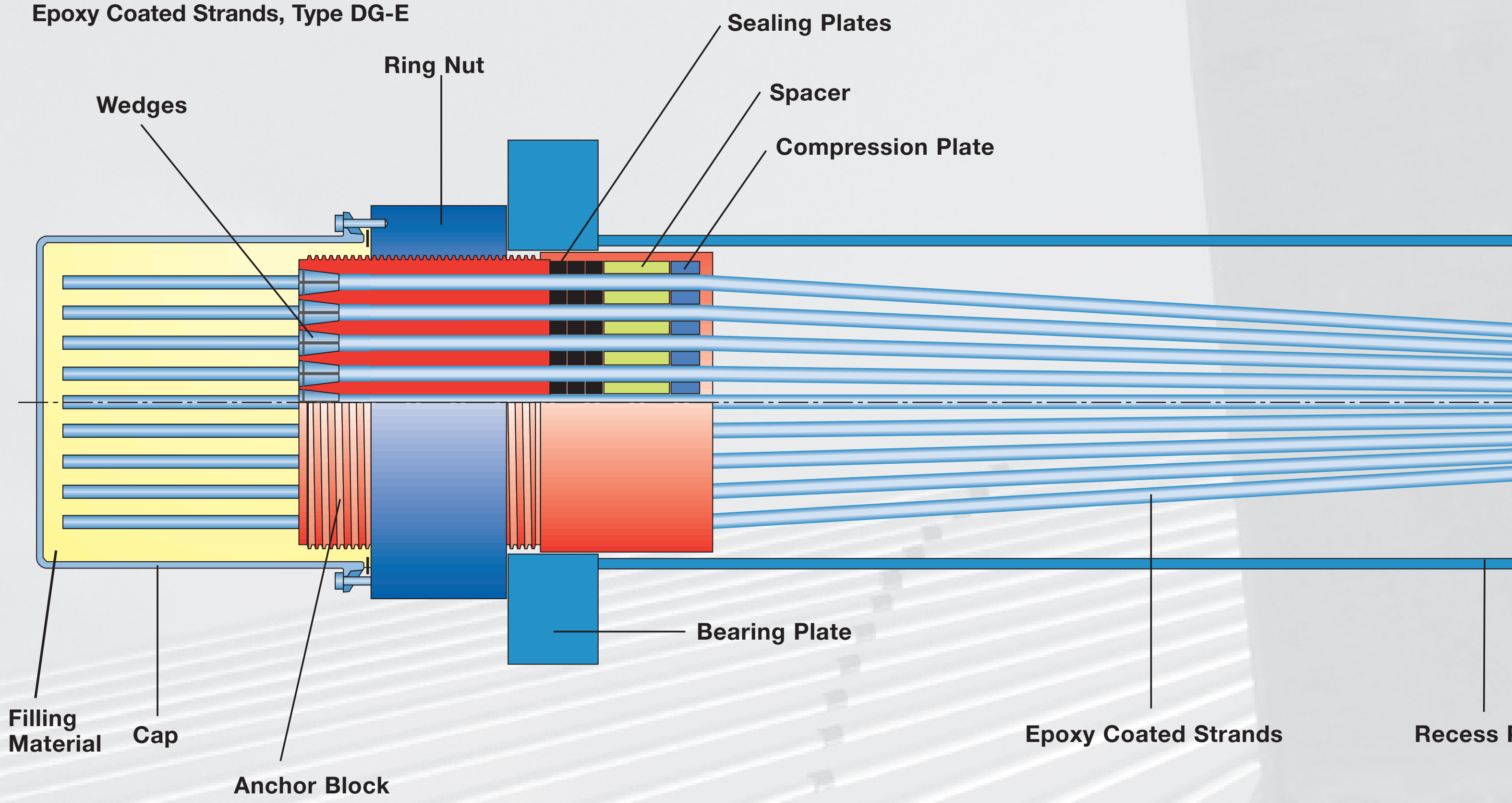
When a DYNA Force™ is installed on a strand, the force in it may be obtained directly by merely attaching the leads from DYNA Force™ to a portable Power Stress unit. No other equipment is needed. DYNA Force™ sensors have been used in many bridge and building structures for the past several years.

DSI supplied two hundred forty sensors for the Waldo Hancock cable stay bridge, Maine, USA. Each cable had six sensors and the cable forces at each stage of construction were monitored with these sensors. Periodic lift-off operations were made on the strands with sensors and a good correlation was observed. The bridge is now open to traffic and the forces in any cable can be monitored at any time using these DYNA Force™ sensors without any disruption to traffic.



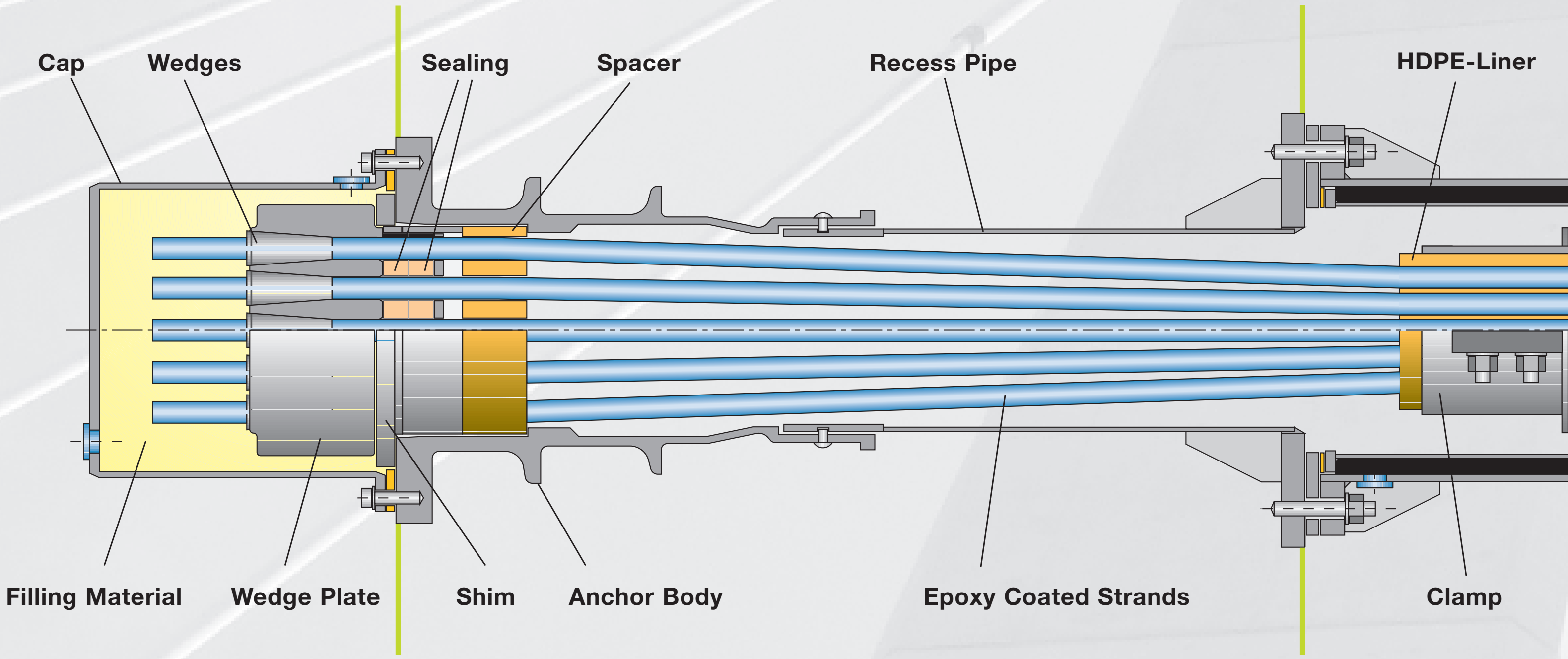
DYNA Grip® Anchorage with Epoxy Coated Strands, Type DG-E

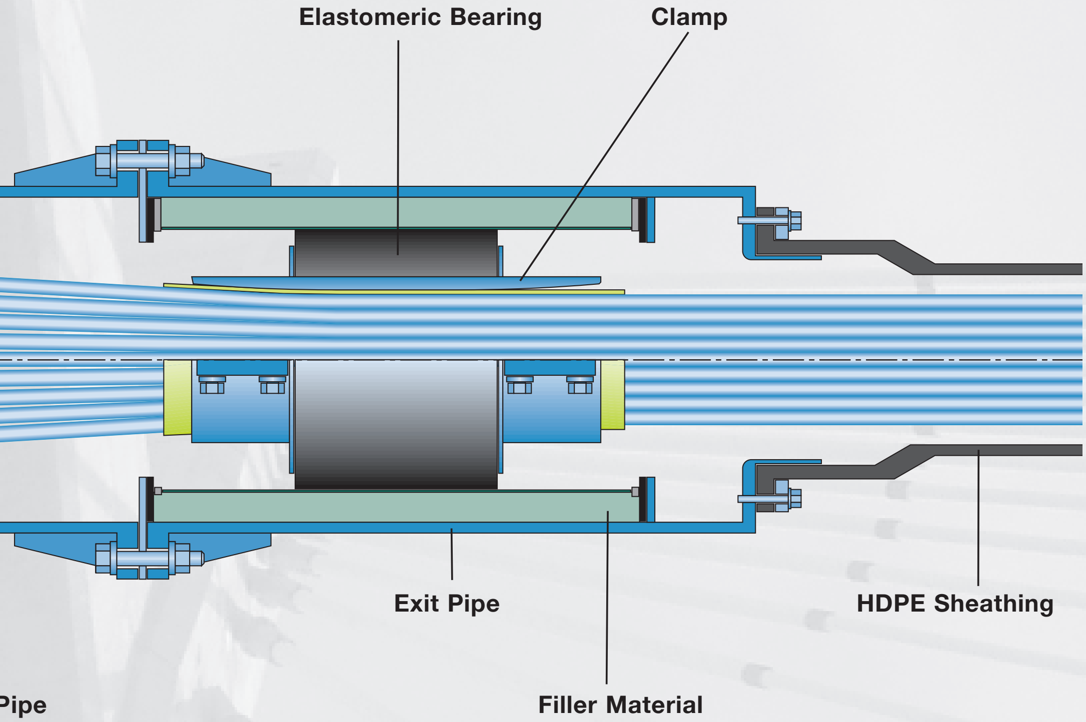
DYNA Grip® Anchorage with Epoxy Coated Strands, Type DG-E



DYWIDAG Extradosed Tendons

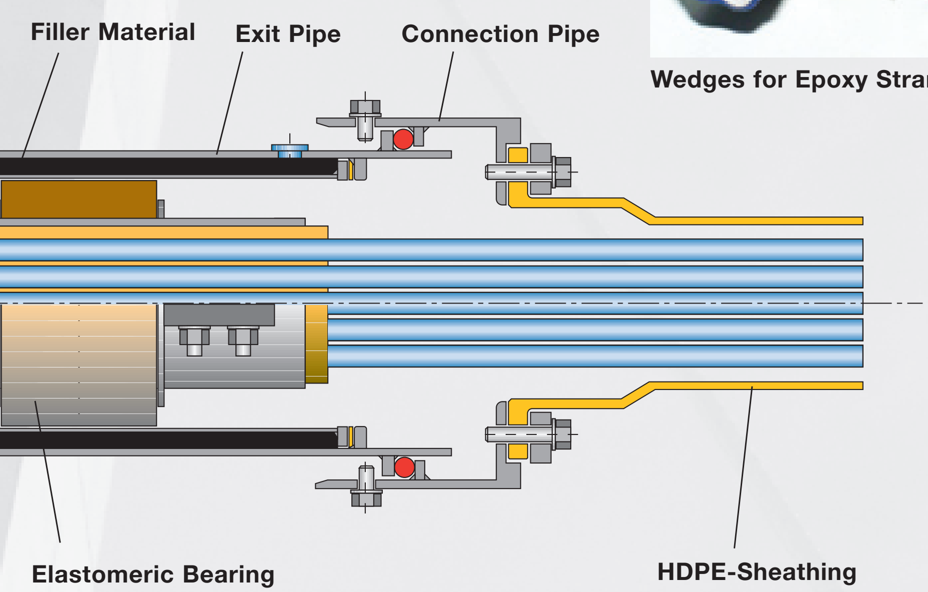
DYWIDAG Extradosed Tendon, Type XD-E






Epoxy coated strand


Wedges for Epoxy Strands



DYNA® Anchorages with Epoxy Coated Strands

Based on the DYNA Bond® and DYNA Grip® Systems, DSI can also offer stay cables using epoxy coated strands.

Epoxy Coated Strand

Epoxy coated strand is manufactured in compliance with ISO 14655:1999. The cold-drawn 7-wire strand is coated with epoxy resin in the shop. The interstices between the 7 wires are completely filled with epoxy resin thus providing an excellent and robust long-time corrosion protection. The epoxy material also reduces fretting action between the individual wires and cushions adjacent strands in deviation areas. Due to the good bond of the epoxy with the steel wires and the ductile behavior of the epoxy material, the possibility of damage to the corrosion protection barrier during stressing is eliminated.

The 3-part wedges are specially designed for epoxy coated strands. The teeth penetrate through the coating so that they grip into the wires of the strand. Fatigue tests conducted on single-strand tendons have proven a dynamic stress range of up to 260 N/mm^2 (upper stress 0.45 GUTS at 2 million load cycles).

DYWIDAG Extradosed Tendons

DYWIDAG Stay Cables can also be used for extradosed tendons. In case of high-stress amplitudes, the strands are anchored with DYNA Bond® or DYNA Grip® Anchorages.
A special anchorage based on DYWIDAG External Tendons was developed for low amplitudes. The picture shows a DYWIDAG Extradosed Cable Type XD-E with an adjustable elastomer bearing incorporating epoxy coated strands.

DYWIDAG Extradosed Cables are replaceable, restressable and destressable.

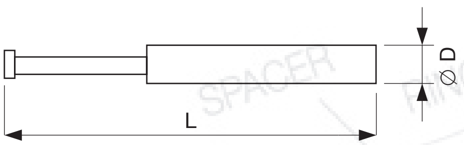
Other solutions can be adopted to project-specific requirements.

Jacks	Type	Capacity [kN]	Cable Type	Max. Strand No.	B [mm]	C [mm]	D [mm]	E [mm]	L [mm]	Weight [kg]	Strand Protrusion [mm]
ConTen Jacks	140 kN	137	All Types	All Types	–	–	65	–	950	~ 17	1100
	180 kN	182	All Types	All Types	–	–	73	–	950	~ 19	1100
Multistrand Jacks	HOZ 3000	3054	DYNA Bond®	12	275	300	385	690	1130	~ 400	470
	HOZ 4000	4204	DYNA Bond®	19	305	366	482	755	1250	~ 600	650
	6800	6803	DYNA Bond®	27	280	395	560	185	1250	~ 1200	1150
	8600	8617	DYNA Bond®	37/61	405	646	750	840	1370	~ 2200	1400
	9750	9748	DYNA Bond®	37	335	470	680	195	1170	~ 1800	1200
	15000	15632	DYNA Bond®	61/108	510	750	980	390	1700	~ 5400	1700
Gradient Jacks	C 27	3500	DYNA Bond®	27	–	–	560 x 610	–	725	~ 400	540 *
	C 37	4200	DYNA Bond® / DYNA Grip®	37	–	–	610 x 610	–	820	~ 520	660 *
	C 61	6800	DYNA Bond® / DYNA Grip®	61	–	–	700 x 700	–	865	~ 700	680 *
	C 73	8400	DYNA Grip®	73	–	–	780 x 760	–	965	~ 820	780 *

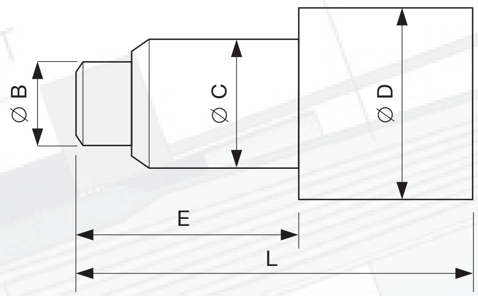
Jack dimensions without lifting devices
Min 2 cm around must be allowed for working space

* measured from bearing plate

ConTen Jacks



Multistrand Jacks



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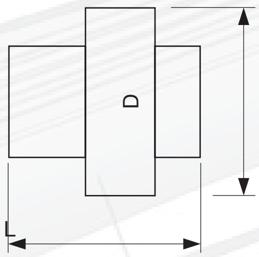


Apollo Steel Arch Bridge, Bratislava, Slovakia

References

Stay Cable Bridges with Bars – with Bond

Name / Project	Service	Country	Year	Client
Maintenance Hall	hangar	Germany	1970	Airport Frankfurt/Main
2. Main Bridge	rail/road	Germany	1972	HOECHST Chemicals, Frankfurt
Sto Domingo Bridge	road	Dominican Rep.	1975	MOP Santo Domingo
Namiki Bridge	road	Japan	1978	Japan Housing Corporation
Matsugayama Bridge	road	Japan	1978	Kanagawa Prefecture Utility Board
Kotaki Bridge	road	Japan	1984	Tannan Cho
Shin Ayabe Bridge	road	Japan	1986	Kyoto Prefectural Government
Yoshimi Bridge	pedestrian	Japan	1987	Saku Cho
Dame Point Bridge	road	USA	1987	Jacksonville Transport
Takinokouen Bridge	road	Japan	1990	Hokkaido Development Agency
Yelcho River Bridge	road	Chile	1989	Ministry of Transportation
Heisei Bridge	road	Japan	1992	Nakano City
Chikuma Bridge	road	Japan	1993	Nagano Prefecture
Scripps Crossing Bridge	pedestrian	USA	1993	University of California
Salpasilta Bridge	pedestrian	Finland	1994	Joenssu Housing Administration
Shinhama Bridge	road	Japan	1994	Saga Prefecture
Lechsteg Bridge	pedestrian	Austria	1995	Local Administration of Reutte
Darby Creek	road	USA	2001	Franklin County, Ohio
Bolognesi Bridge	road	Peru	2002	Ministry of Transportation

Stay Cable Bridges with Bars – without Bond and DYNA®-Shield Corrosion Protection

Marsupial Bridge	pedestrian	USA	2005	City of Milwaukee

Stay Cable Bridges, DYNA Bond® System

Name / Project	Service	Country	Year	Client
Muna Water Reservoir	reservoir	Saudi Arabia	1985	Ministry of Public Works Saudi Arabia
Quincy Bridge	road	USA	1987	Illinois Department of Transportation
Olympic Grand Bridge	road	South Korea	1988	City of Seoul, Highway Commission
Alamillo Bridge Sevilla	road	Spain	1991	Junta de Andalusia
Paterna Bridge	road	Spain	1991	Provincia de Valencia
Clark Bridge Alton	road	USA	1993	Illinois Department of Transportation
Hakusan Bridge	road	Japan	1994	Niigata Prefecture
Oze Bridge	road	Japan	1994	Gunma Prefecture
Kap Shui Mun Bridge	rail/road	Hong Kong	1995	Government of HK Highway Dept.
Haeng Ju Bridge	road	South Korea	1995	City of Seoul, Highway Commission
Cochrane Bridge	road	USA	1995	Alabama Department of Transportation
6. October Bridge Cairo	road	Egypt	1996	Ministry for Roads and Bridges
Usti nad Labem Bridge	road	Czech Rep.	1997	City of Usti
Interstate Gateway 65 Arch Bridge	road	USA	1997	Indiana Dept of Transportation
Sidney Lanier Bridge	road	USA	1998	Georgia Dept of Transportation
Second Street Bridge	road	USA	1998	Indiana Dept of Transportation
Mondeville Bridge	road	France	1999	Calvadas Administration
Dubrovnik Bridge	road	Croatia	2000	Hrvatska Uprava za Ceste
Hoshinofurusato Bridge	road	Japan	2000	Hokkaido Development
Lipon Bridge	road	Finland	2000	Road Administration
Blautal Bridge	road	Germany	2001	Local Administration, Ulm
Williamette River Bridge	pedestrian	USA	2001	City of Eugene, Oregon
Mc Kenzie River Bridge	road	USA	2002	Wildish Land Company
Fitchburg Bridge	road	USA	2002	Massachusetts Highway
La Plata	road	Puerto Rico	2006	PR Highway Authority
Gimpo Bridge	road	South Korea	2009	Korea Land Corporation

Stay Details			Bridge Geometry [m]			
No.	Type	Tonnage [t]	No. of Pylons	Width	Main Opening	Total Length
20	multi bar	59	10	102,0	135 + 135	321
104	multi bar	290	1	31,0	94 + 148 + 26	300
8	multi bar	8	2	28,5	30 + 60 + 30	120
8	multi bar	9	1	7,0	40 + 40	81
16	multi bar	26	1	4,2	96,5	130
12	multi bar	11	1	7,2	44 + 44	90
20	multi bar	95	1	10,8	110	392
6	multi bar	5	1	4,3	45 + 45	89
288	multi bar	1800	2	32,3	198 + 396 + 198	2.005
20	multi bar	50	2	14,8	44 + 80 + 44	169
56	mono bar	51	2	6,4	50 + 150 + 50	250
24	multi bar	50	1	10,5	75 + 75	152
48	multi bar	108	2	15,3	59 + 56	116
15	mono bar	3	1	5,0	35 + 10	45
12	mono bar	3,4	1	4,5	20 + 40	60
40	multi bar	82	1	11,3	79 + 69	150
14	mono bar	3,2	1	4,3	32 + 24	56
104	mono bar	5	2	10,0	11 + 65 + 11	87
32	multi bar	20	arch	22,7	150	150
4	mono bar	1,2	6	3,3	5 x 24 + 29	196

Stay Details				Bridge Geometry [m]			
No.	Strand Type	Cable Type	Tonnage [t]	No. of Pylons	Width	Main Opening	Total Length
616	wax / PE	DB 6 - 15	495	44		60 + 220 + 60	335
56	epoxy flobond	DB-E 37, 61	234	2	17,7	134 + 274 + 134	1.356
48	bare	DB-B 19, 37, 61	330	1	30,0	150 + 150	300
28	epoxy flobond	DB-E 61	330	1	32,0	200	250
10	galv./ wax / PE	DB-P 61	26	1	17,0	64 + 34	160
40	epoxy flobond	DB-E 48	351	2	31,4	92 + 231 + 92	415
20	bare	DB-B 27	23	1	11,5	61 + 61	122
52	bare	DB-B 19	104,3	1	16,7	115 + 115	230
176	galv./ wax / PE	DB-P 61, 75, 91, 108	2500	2	35,2	430 + 4 x 80 + 70	720
32	epoxy coated	DB-E 27	55	2	14,5	50 + 120 + 50	380
96	bare	DB-31, DB-73	800	2	24,0	110 + 238 + 110	458
48	galv./ wax / PE	DB-P 12, 19	37,6	1	10,1	67 + 67	133
30	galv./ wax / PE	DB-P 12, 19	35	1	24,0	132	198
16	bare	DB-12, DB-27	8	arch	30,0	40	40
176	bare	DB-B 19 - 61	875	2	24,2	190 + 381 + 190	761
40	bare	DB-B	49	1		71 + 71	142
12	galv./ wax / PE	DB-P 19, 27	10	1	13,8	31 + 31	62
38	galv./ wax / PE	DB-P 27, 61	310	1	14,0	87 + 304 + 90	481
60	bare	DB-B 37, 48	226	1	15,5	132	265
13	galv./ wax / PE	DB-P 37, 61	40	1	12,5	74 + 25	99
8	galv./ wax / PE	DB-P 27	8	1	12,0	41 + 29	685
6	wax / PE	DB-P 48	12	2	6,5	23 + 103 + 23	149
6	wax / PE	DB-P 48	16	2		37 + 131 + 37	205
52	wax / PE	DB-P 27	52	2	13,6	51 + 109 + 36	196
96	wax / PE	DB-P 27, 37	153	2	29,2	80 + 160 + 80	402
10	galv./ wax / PE	DB-P 27, 37	18	1	20,3	75 + 35	110

References

Stay Cable Bridges, DYNA Grip® System

Name / Project	Service	Country	Year	Client
Rosario Victoria Bridge	road	Argentina	2000	Ministerio servicios publicos
Zevenaar Bridge	road	Netherlands	2001	NS Railinfrabeheer
Nelson Mandela Bridge	road	South Africa	2002	Provincial Administration
Kampen Bridge	road	Netherlands	2002	Rijswater Bouwdienst
6th Street Bridges	road	USA	2002	City of Milwaukee
Maumee Bridge	road	USA	2003	City of Toledo
Lane Avenue Bridge	road	USA	2003	Columbus, Ohio
Provencher Bridge	pedestrian	Canada	2003	Winnipeg
Apollo Arch Bridge	road	Slowakia	2004	Metro Bratislava
Ponte de Machico	road	Madeira	2004	Governo Regional da Madeira
Ziegelgrabenbrücke Rügen	road	Germany	2005	DEGES
Freddie Mac Bridge	pedestrian	USA	2005	Freddie Mac
Nymburk Bridge	road	Czech Rep.	2005	Ředitelství silnic a dálnic ČR
Pomeroy Mason	road	USA	2005	Ohio Department of Transportation
Prospect Verona Bridge	road	USA	2006	Maine Department of Transportation
Pont de Volonne	road	France	2006	Département Alpes-de-Haute-Provence
Gajo Arch Bridge	road	South Korea	2007	Geoje City
Karlsbad	road	Czech Rep.	2007	Ředitelství silnic a dálnic ČR
North Ave Bridge	road	USA	2007	City of Chicago
Rheinbrücke Wesel	road	Germany	2008	Landesbetrieb Strassen NRW
Manises-Paterna	road	Spain	2008	Diputación de Valencia
Pitt River Bridge	road	Canada	2008	Vancouver
Sae Poong Bridge	road	South Korea	2009	Iksan Construction and Management Administration
Elbow River Bridge	road	Canada	2009	Calgary Stampede
Albox	road	Spain	2009	Albox County
Bacher Lechbrücke	road	Austria	2009	Land Tirol

Extradosed Bridges

Odawara Blueway Bridge	road	Japan	1994	Japan Highway Public Corporation
Shouyou Bridge	road	Japan	1996	Akita pref.
Karato Bridge	road	Japan	1998	Hanshin Expressway Company Ltd.
Mactan Bridge	road	Philippines	1999	Department of public Works and Highways of Philippines
Shikari Bridge	road	Japan	2000	Hokkaido Development
Matakina Bridge	road	Japan	2000	Okinawa pref.
Hozu Bridge	road	Japan	2000	Kyoto pref.
Koror Babelthuap Bridge	road	Palau	2000	Republic of Palau
Sashiki Bridge	road	Japan	2001	Kumamoto pref.
Fukaura Bridge	road	Japan	2001	Niigata pref.
Nakanoike Bridge	road	Japan	2001	Osaka Prefectural Road Public Corp.
Tobiuo Bridge	road	Japan	2002	Shizuoka pref.
Arakogawa Bridge	road	Japan	2003	Central Japan Railway Company
Sannohe Bridge	road	Japan	2004	Aomori pref./East Japan Railway Company
Noikura Bridge	road	Japan	2005	Japan Greensource Agency Kyusyu Branch
Domovinski Bridge, Zagreb	road	Croatia	2005	Grad Zagreb
Nanchiku Bridge	road	Japan	2007	Fukuoka pref.
Satonojou Bridge	road	Japan	2007	Kumamoto pref.
Yanagawa Bridge	road	Japan	2007	Iwate pref.
Kanazawatagami Bridge	road	Japan	2007	Ishikawa pref.
Sannaimaruyama Bridge	road	Japan	2008	Japan Railway Construction, Transport/Technology (JRTT)
Hirano Bridge	road	Japan	2008	West Japan Railway Company
Trois Bassins	road	La Reunion	2007	Conseil Régional de La Réunion
Ohnogawa Bridge	road	Japan	2008	Japan Railway Construction, Transport/Technology (JRTT)
Bridge Povazska Bystrica	road	Slovakia	2009	Slovenská národná dialničná spoločnosť
Bridge Ziarnovica	road	Slovakia	2009	Slovenská národná dialničná spoločnosť
Earthquake Memorial Bridge	road	AJK, Pakistan	2010	National Highway Authorities (NHA)

Stay Details				Bridge Geometry [m]			
No.	Strand Type	Cable Type	Tonnage [t]	No. of Pylons	Width	Main Opening	Total Length
128	galv./ wax / PE	DG-P 31, 37, 55, 61, 73	770	2	22,8	120 + 350 + 120	590
16	galv./ wax / PE	DG-P 32, 44	18	4	15,5	15 + 50 + 15	80
52	galv./ wax / PE	DG-P 19, 31, 37, 55	104	2	14,2	42 + 176 + 66	284
24	galv./ wax / PE	DG-P 37, 55, 91	187	1	20,0	91 + 150	241
48	wax / PE	DG-P 31, 37	205	2	17,5	2 x (38 + 60)	583
40	epoxy flofil	DG-E 121, 157	914	1	38,7	187 + 187	2.682
20	wax / PE	DG-P 19	19	1	34,2	57 + 57	113
44	galv./ wax / PE	DG-12, 14	45	1	7,0	83 + 110	192
66	galv./ wax / PE	DG-P 12	30	2 arches	32,0	231	231
8	galv./ wax / PE	DG-P 12	2	2	10,2	17 + 36 + 19	72
32	galv./ wax / PE	DG-P 37	150	1	16,0	198 + 126	583
6	wax / PE	DG-P 7	2,3	2	3,9	44	49
24	galv./ wax / PE	DG-P 55	60	2	16,2	41 + 132 + 41	214
48	wax / PE	DG-P 19, 31, 37, 55, 61	227	2	23,3	74 + 206 + 74	354
40	epoxy flofil	DG-E 61, 71	640	2	17,5	146 + 354 + 146	646
22	galv./ wax / PE	DG-P 19, 31	26	2	11,0	32 + 102 + 32	166
80	galv./ wax / PE	DG-P 12	23	2x3 arches	17,0	90 + 150 + 90	330
32	galv./ wax / PE	DG-P 12, 19	18	2	14,9	26 + 64 + 29	121
24	wax / PE	DG-P 19,31	10	2	24,8	26 + 77 + 26	128
72	galv./ wax / PE	DG-P 37, 55	700	1	29,2	335	773
34	galv./ wax / PE	DG-P 31, 37, 55	106	1	22,4	53 + 92	145
96	galv./ wax / PE	DG-P31,61	275	2	48,0	95 + 190 + 95	380
114	galv./ wax / PE	DG-P12,37,55,61	505	3	23,9	85 + 220 + 220 + 85	875
28	wax / PE	DG-P 12, 19	22	1	12,5	48,5	64
11	galv./ wax / PE	DG-P 31, 37, 55	23	1	13,5	23 + 64 + 24	112
11	galv./ wax / PE	DG-P 31, 37, 55	15	1	11,1	48	68
64	epoxy coated	MC 19	60	2	13,0	74 + 122 + 74	268
112	bare	SB 37	231	2	15,5	180	380
128	bare	VC 37	180	4	15,4	140	285
120	epoxy coated	DB-E 48	300	2	17,5	185	410
320	bare	MC 19		4	26,0	140	610
120	epoxy coated	MC19, 27		1	11,3	109	199
64	bare	MC 19	49	2	16,3	100	366
48	bare	MC 27	147	2	11,6	82 + 250 + 82	414
64	epoxy coated	VC 19	52	2	13,9	105	223
48	epoxy coated	MC 19	37	2	13,5	90	140
20	bare	VC 37	28	1	21,4	60	122
64	epoxy coated	VC 37	116	2	25,8	130	385
48	bare	MC 19	37	2	12,7	90	246
120	epoxy coated	MC 19, 37	188	2	10,3	200	400
64	bare	MC 27	72	2	10,0	135	273
64	galv./ wax / PE	DB-P 48	152	2	34,0	72 + 120 + 72	264
64	epoxy coated	VC 37	98	2	23,0	110	248
48	bare	MC 12	20	2	13,8	77	186
48	epoxy coated	MC 27, 37	82	1	16,0	132	264
28	bare	MC 27	38	1	19,8	84	166
132	epoxy coated	MC 27	180	3	16,1	150	450
32	epoxy coated	VC 19	18	2	8,0	63	132
34	galv./ wax / PE	DG-P 37	100	2	22,0	104	240
32	epoxy coated	MC 27	48	1	12,4	113	285
112	galv./ wax / PE	DG-P 37	214	7	30,5	122	969
24	galv./ wax / PE	DG-P 31, 37	27	2	26,1	80	240
56	galv./ wax / PE	DB-P 19, 27	120	1	15,6	123 + 123	246

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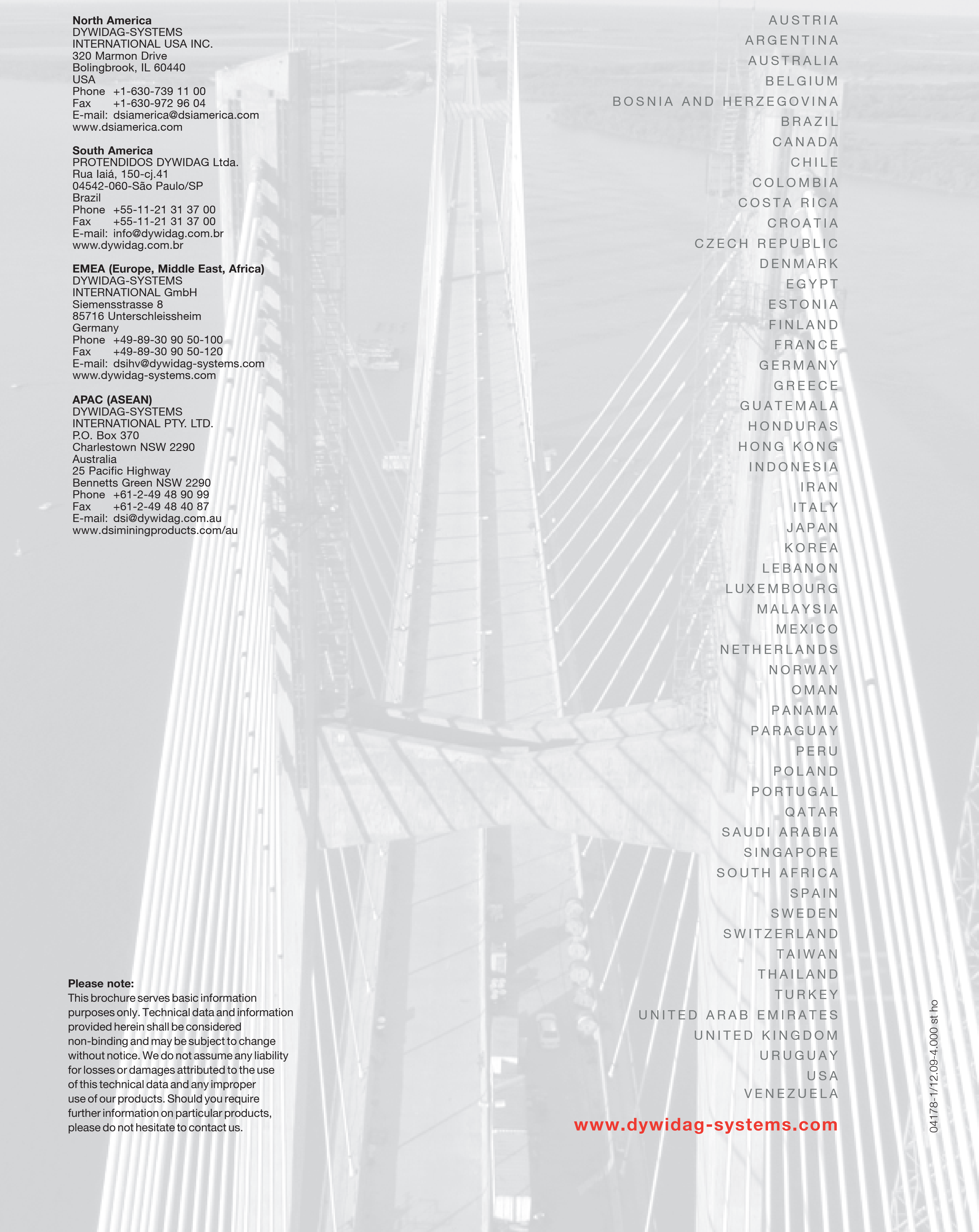

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